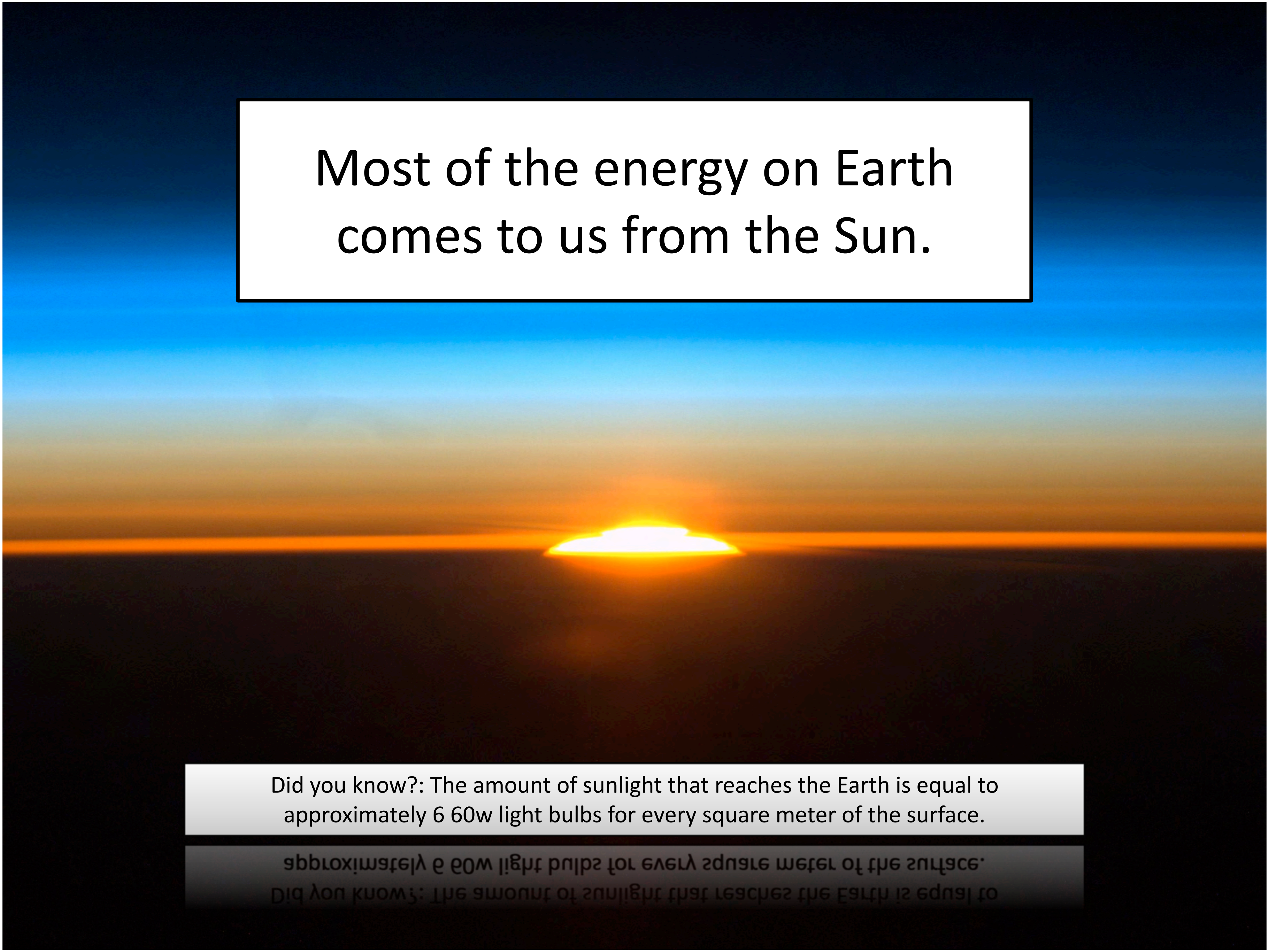
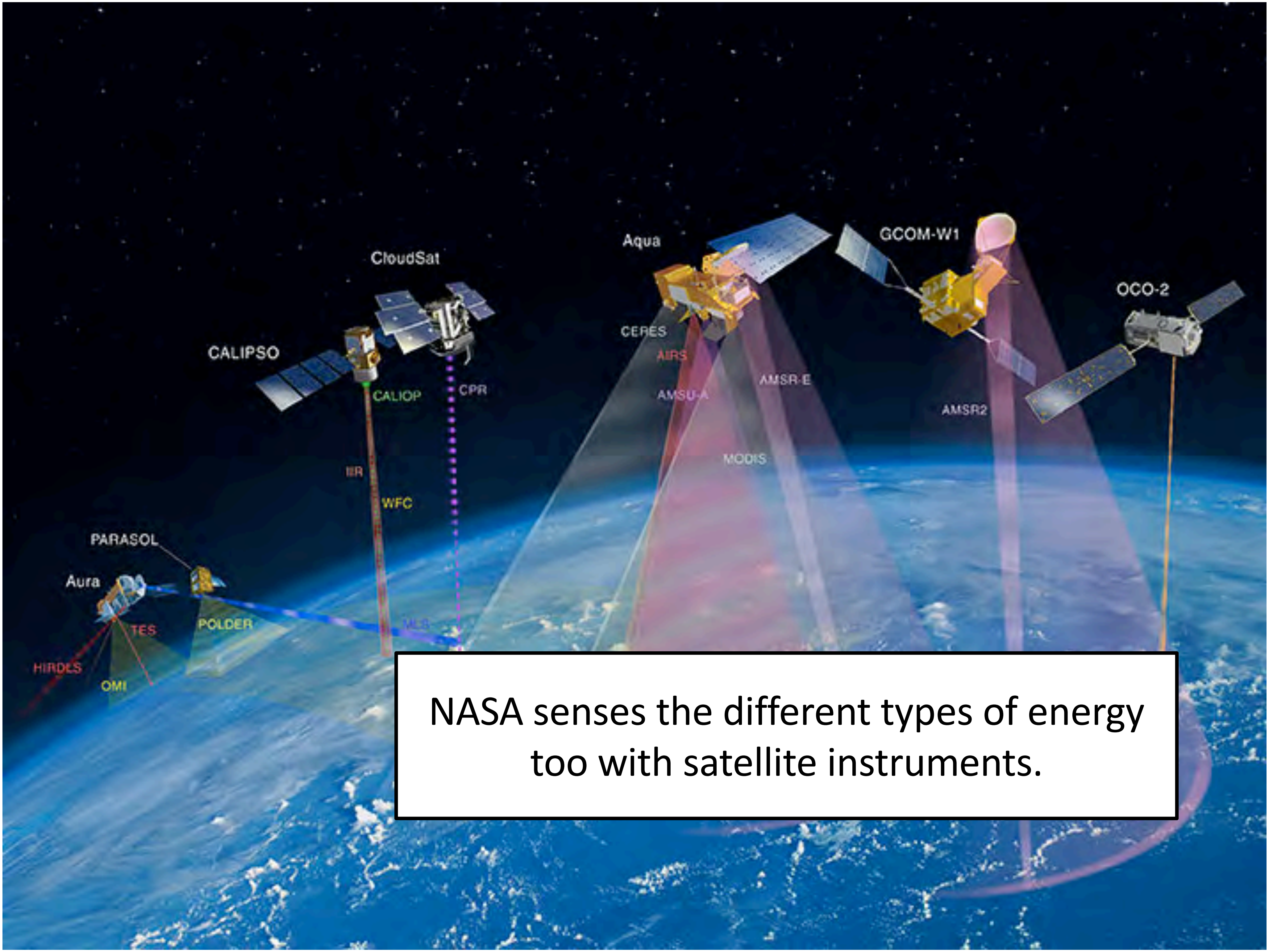

Earth's Energy Budget:
A Story

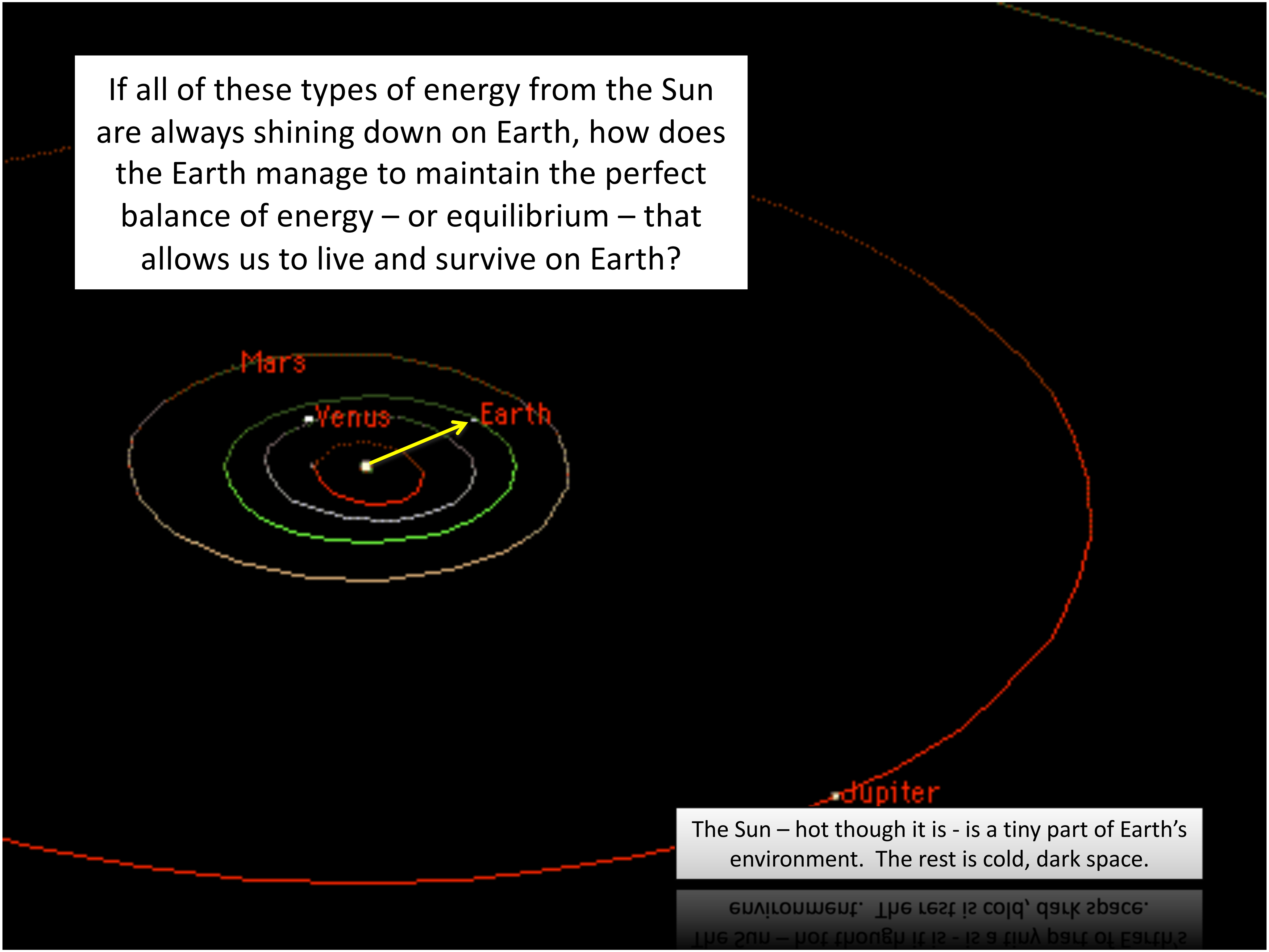

Most of the energy on Earth comes to us from the Sun.
Did you know?: The amount of sunlight that reaches the Earth is equal to approximately 6 60w light bulbs for every square meter of the surface.

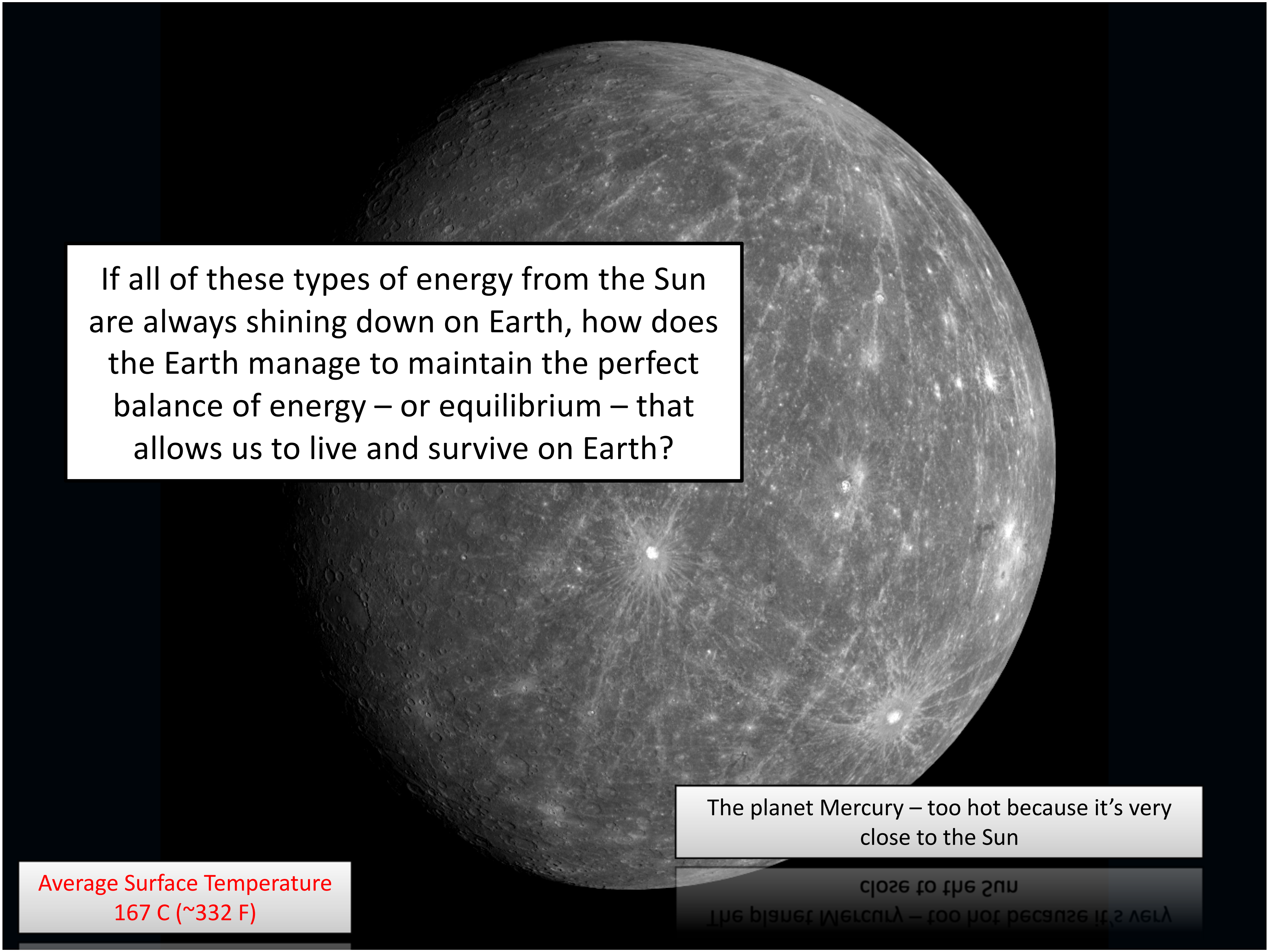
We can sense that energy in different ways. We see the things around us because of visible light…


… And we feel the heat from a campfire, which is infrared energy.



NASA senses the different types of energy too with satellite instruments.


If all of these types of energy from the Sun are always shining down on Earth, how does the Earth manage to maintain the perfect balance of energy – or equilibrium – that allows us to live and survive on Earth?
Mars
Venus
Earth
Jupiter
The Sun – hot though it is - is a tiny part of Earth's environment. The rest is cold, dark space.



If all of these types of energy from the Sun are always shining down on Earth, how does the Earth manage to maintain the perfect balance of energy – or equilibrium – that allows us to live and survive on Earth?
The planet Mercury – too hot because it's very close to the Sun
Average Surface Temperature
167 C (~332 F)

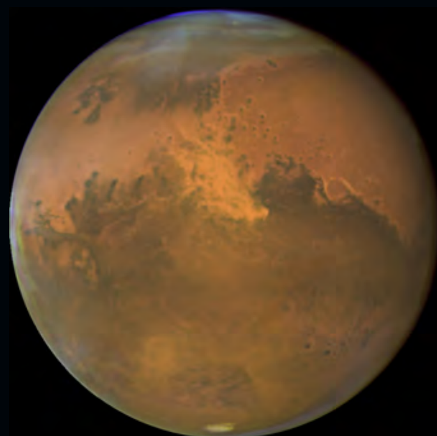

If all of these types of energy from the Sun are always shining down on Earth, how does the Earth manage to maintain the perfect balance of energy – or equilibrium – that allows us to live and survive on Earth?
The planet Mars – “too cold” because it is farther from the Sun and has a very thin atmosphere.
Average Surface Temperature - 65 C (~-85 F)

If all of these types of energy from the Sun are always shining down on Earth, how does the Earth manage to maintain the perfect balance of energy – or equilibrium – that allows us to live and survive on Earth?
3rd rock from the Sun. Still too cold for life.
Average Surface Temperature - 18 C (~0 F)

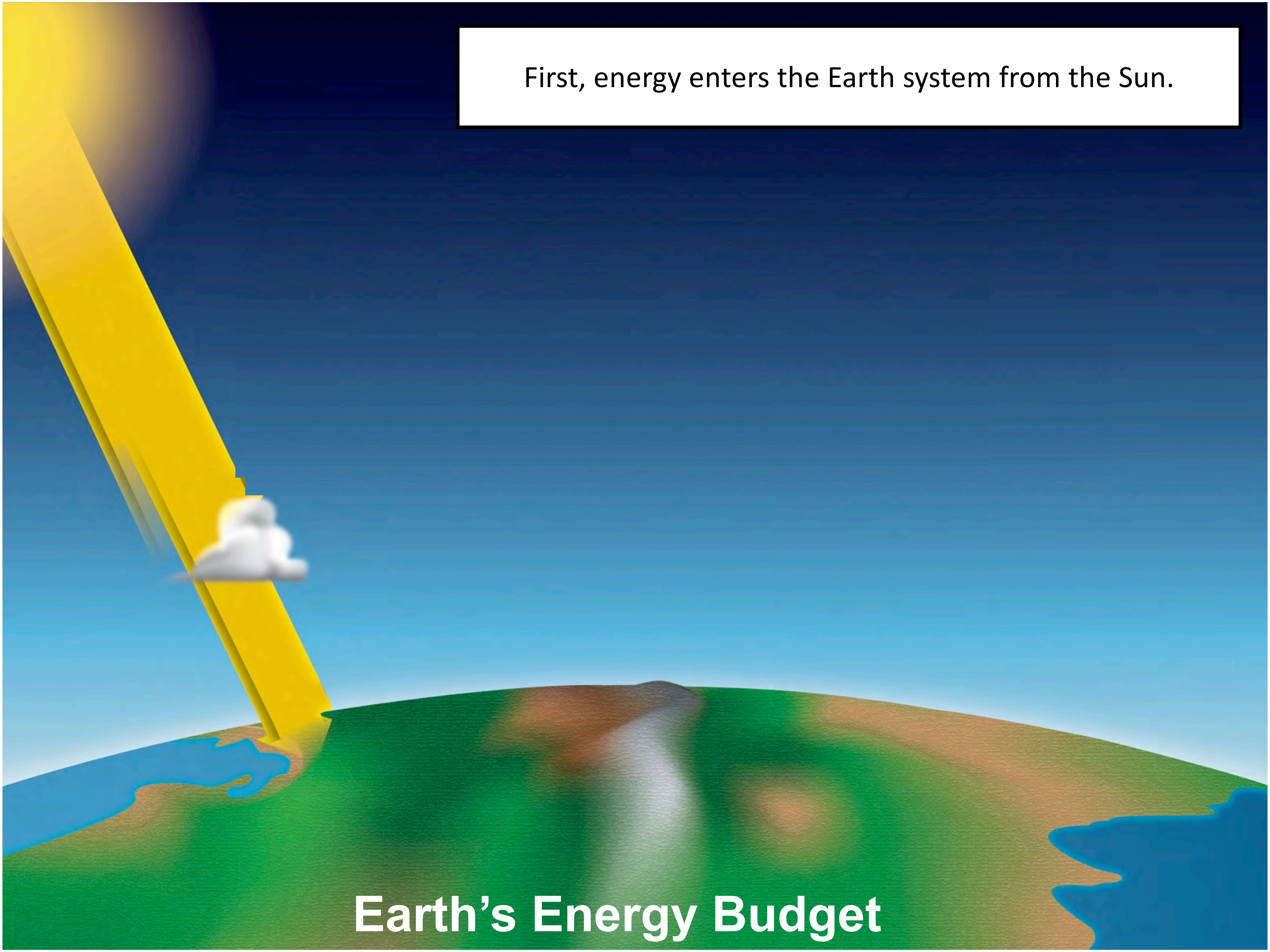
If all of these types of energy from the Sun are always shining down on Earth, how does the Earth manage to maintain the perfect balance of energy – or equilibrium – that allows us to live and survive on Earth?

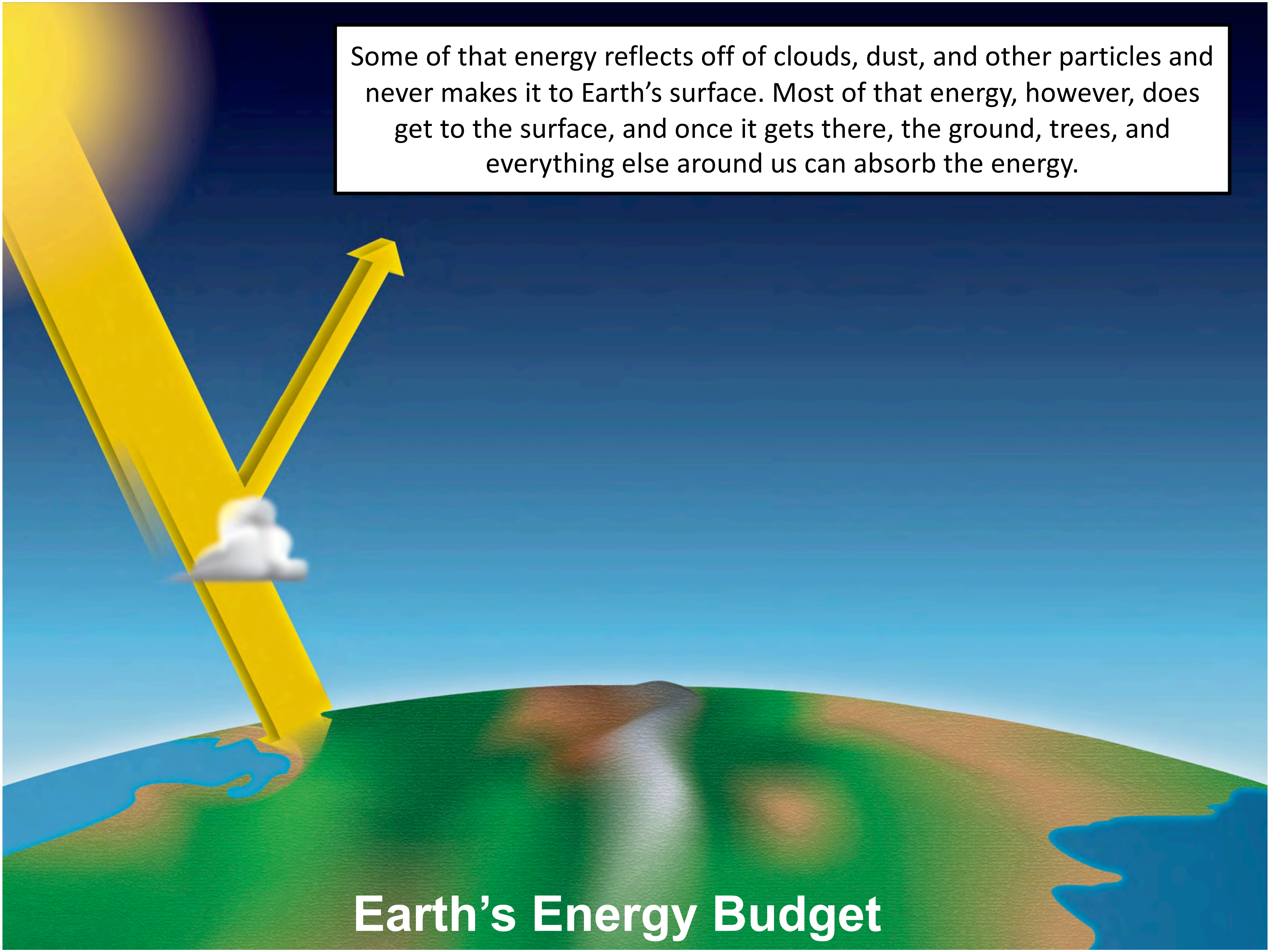
The planet Earth with its atmosphere – just the right balance for life to survive and thrive.

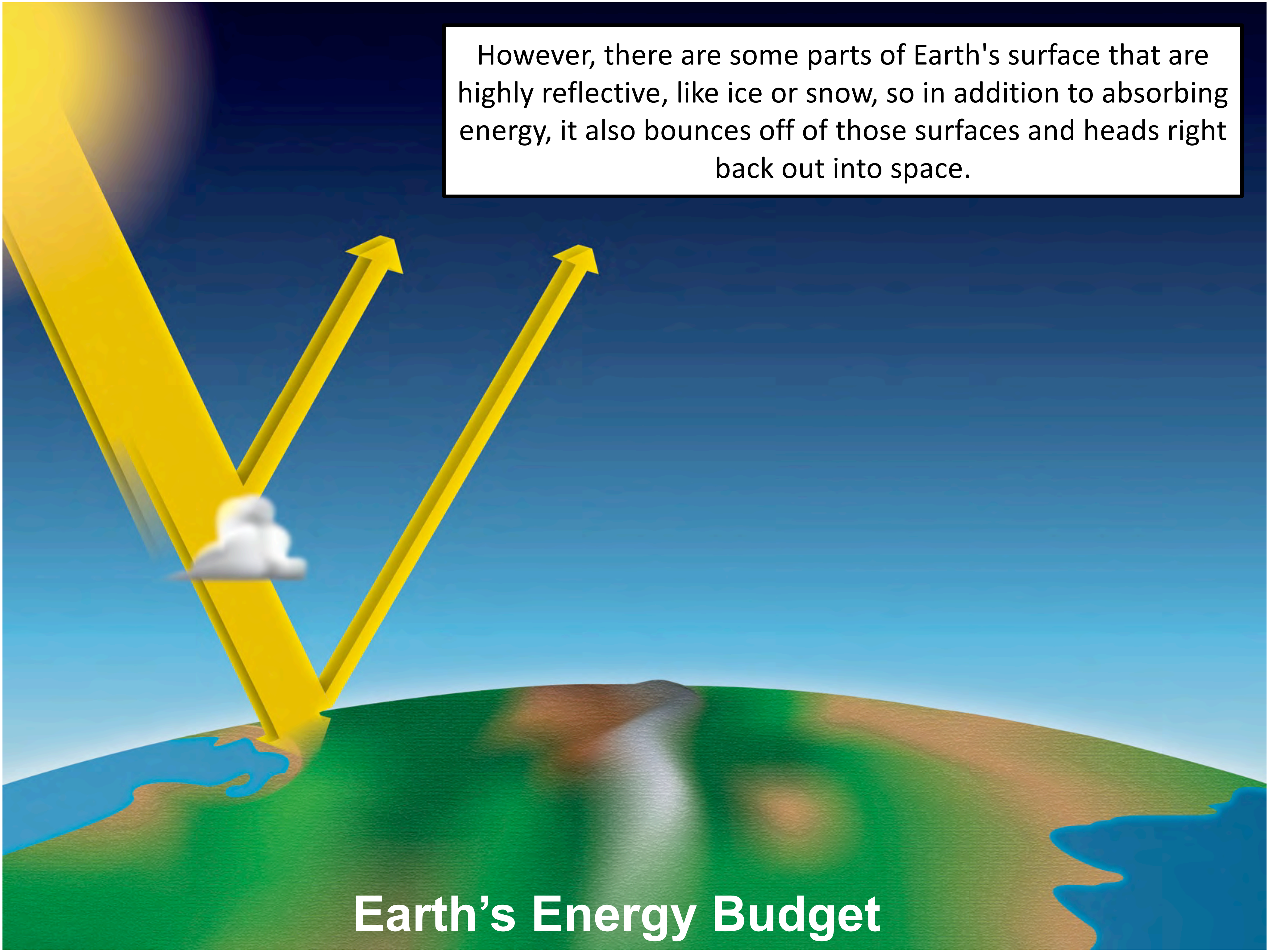
Average Surface Temperature
15 C (~59F)



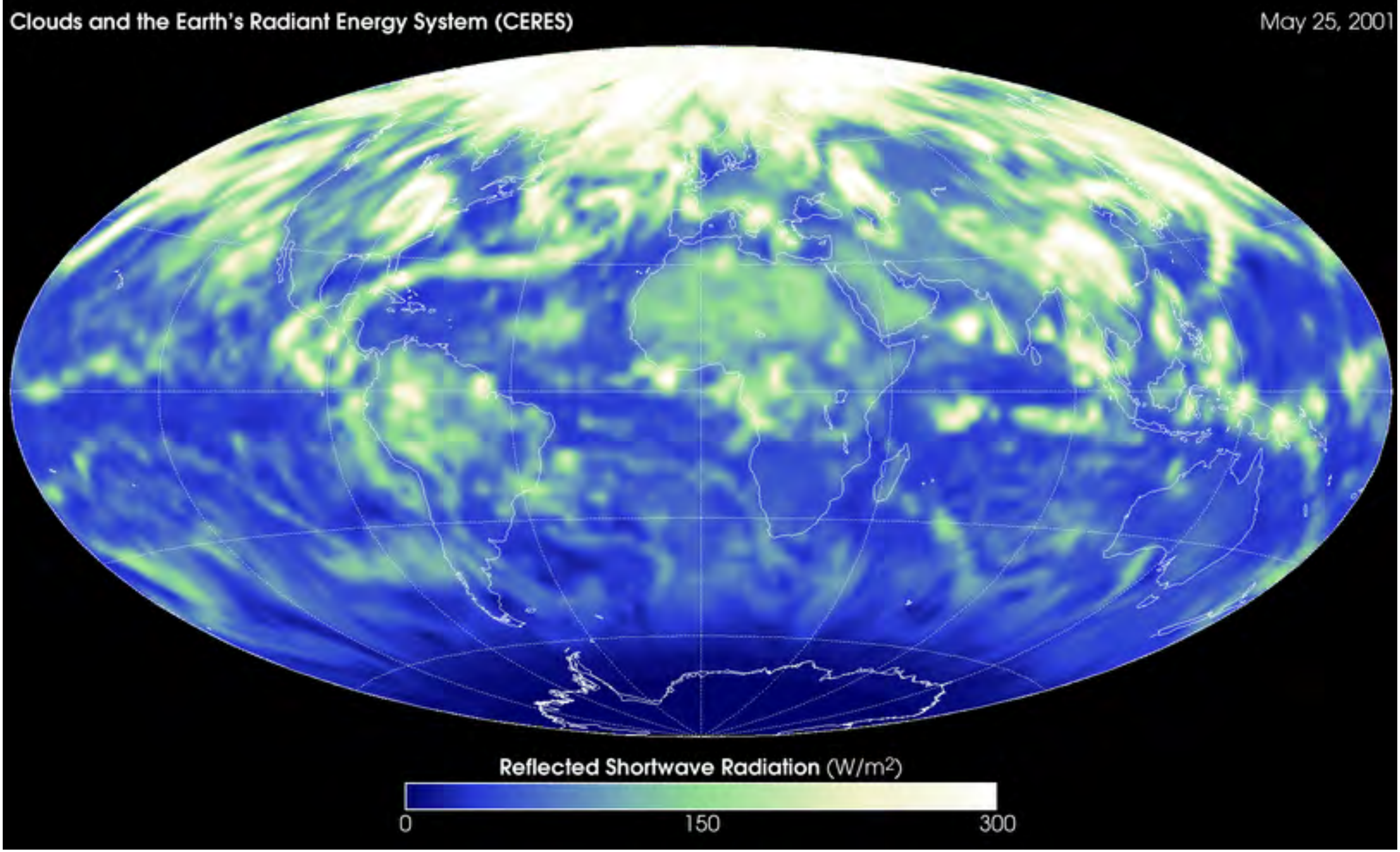
The temperatures of Earth and all the planets are determined by their "Energy Budget."

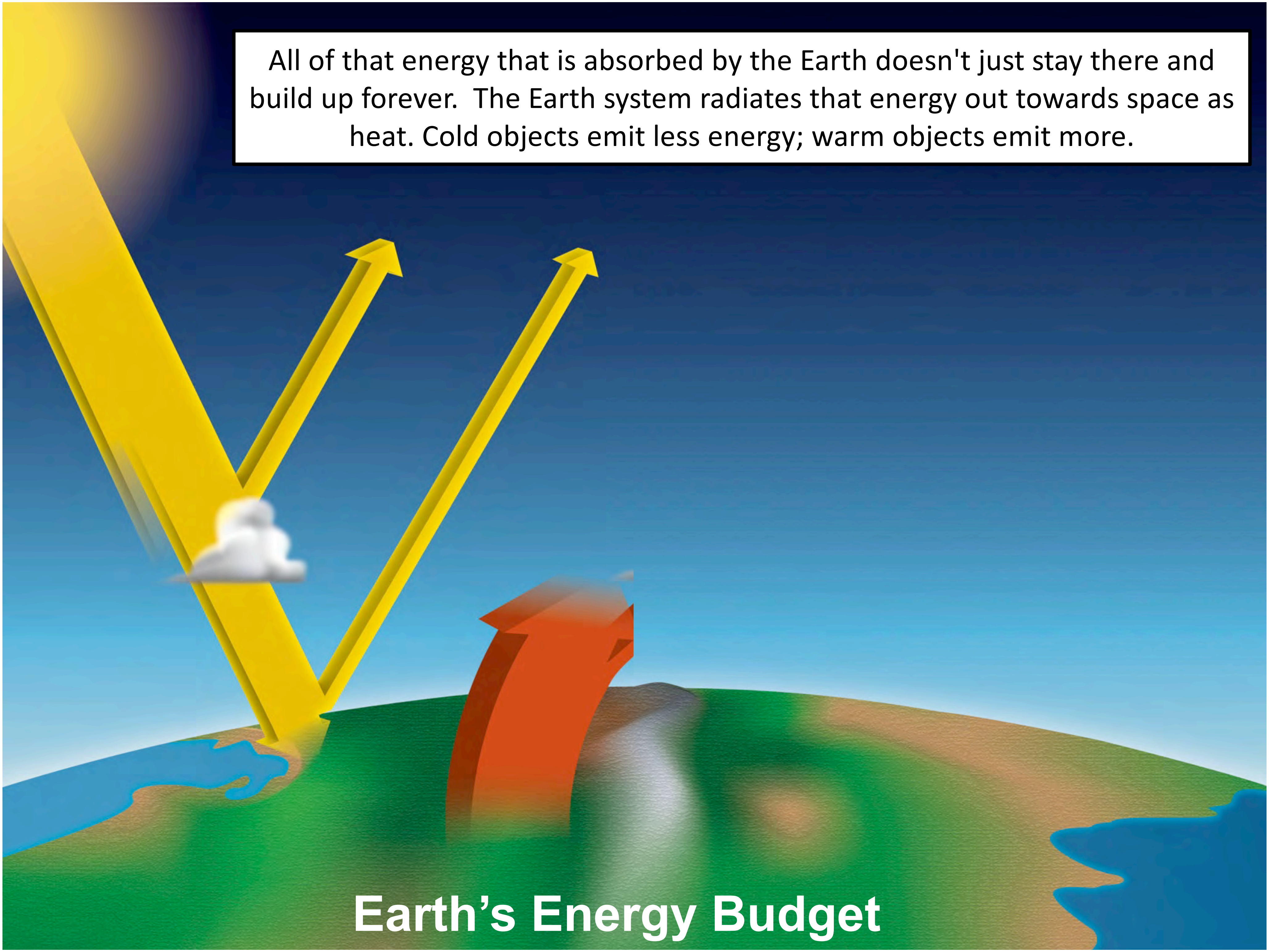

First, energy enters the Earth system from the Sun.
Earth’s Energy Budget

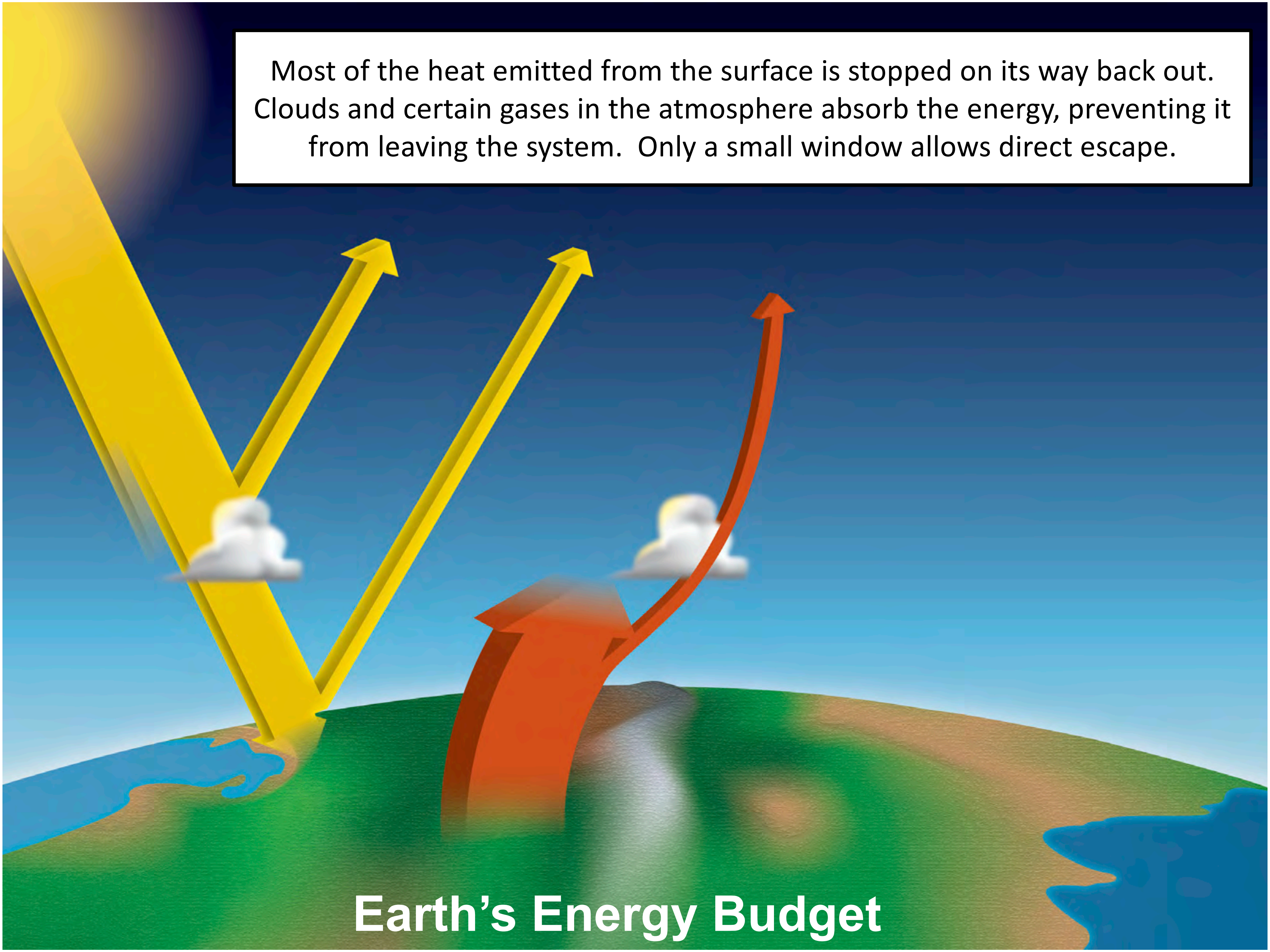

Some of that energy reflects off of clouds, dust, and other particles and never makes it to Earth’s surface. Most of that energy, however, does get to the surface, and once it gets there, the ground, trees, and everything else around us can absorb the energy.
Earth’s Energy Budget

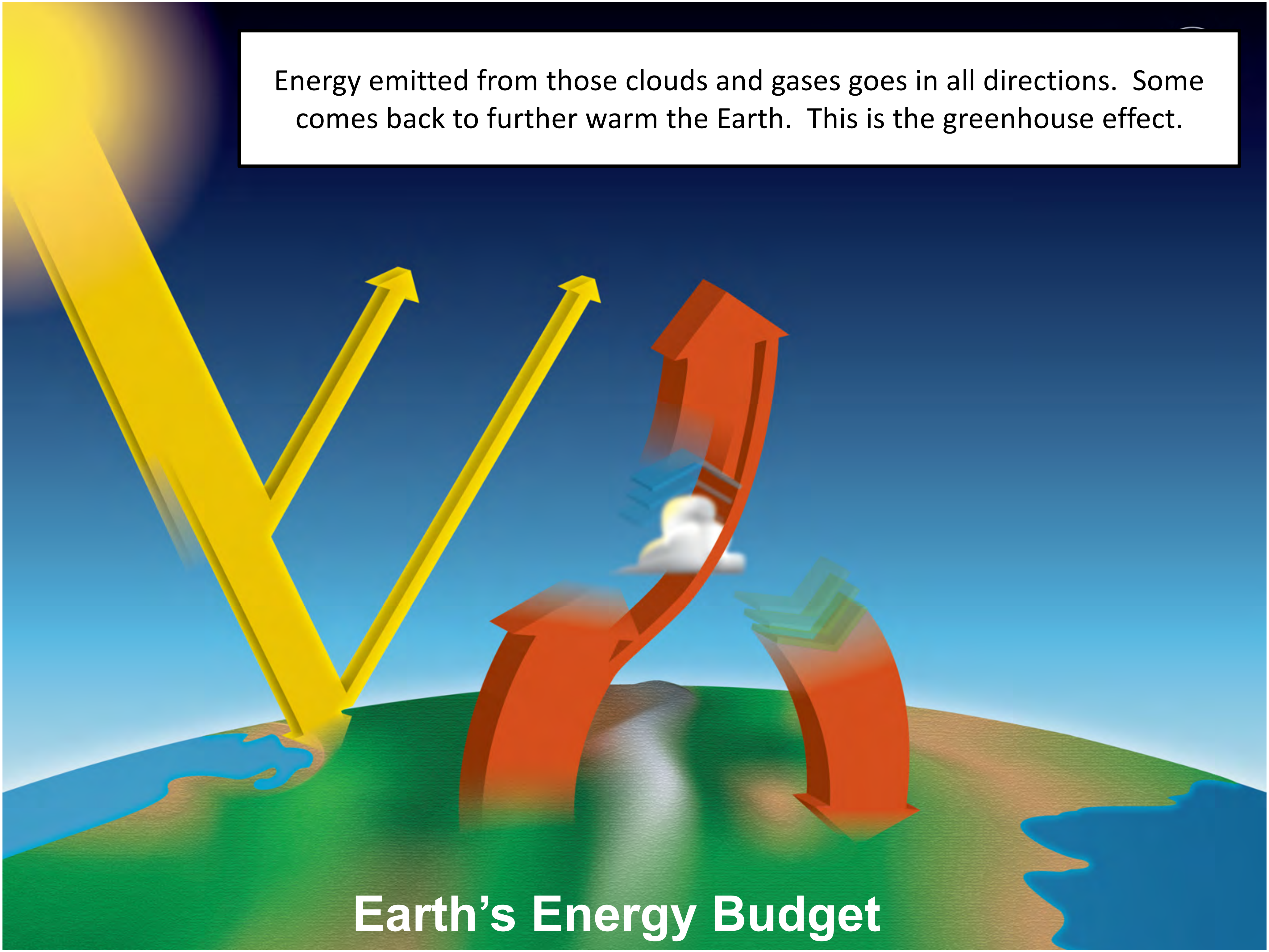

However, there are some parts of Earth's surface that are highly reflective, like ice or snow, so in addition to absorbing energy, it also bounces off of those surfaces and heads right back out into space.
Earth’s Energy Budget

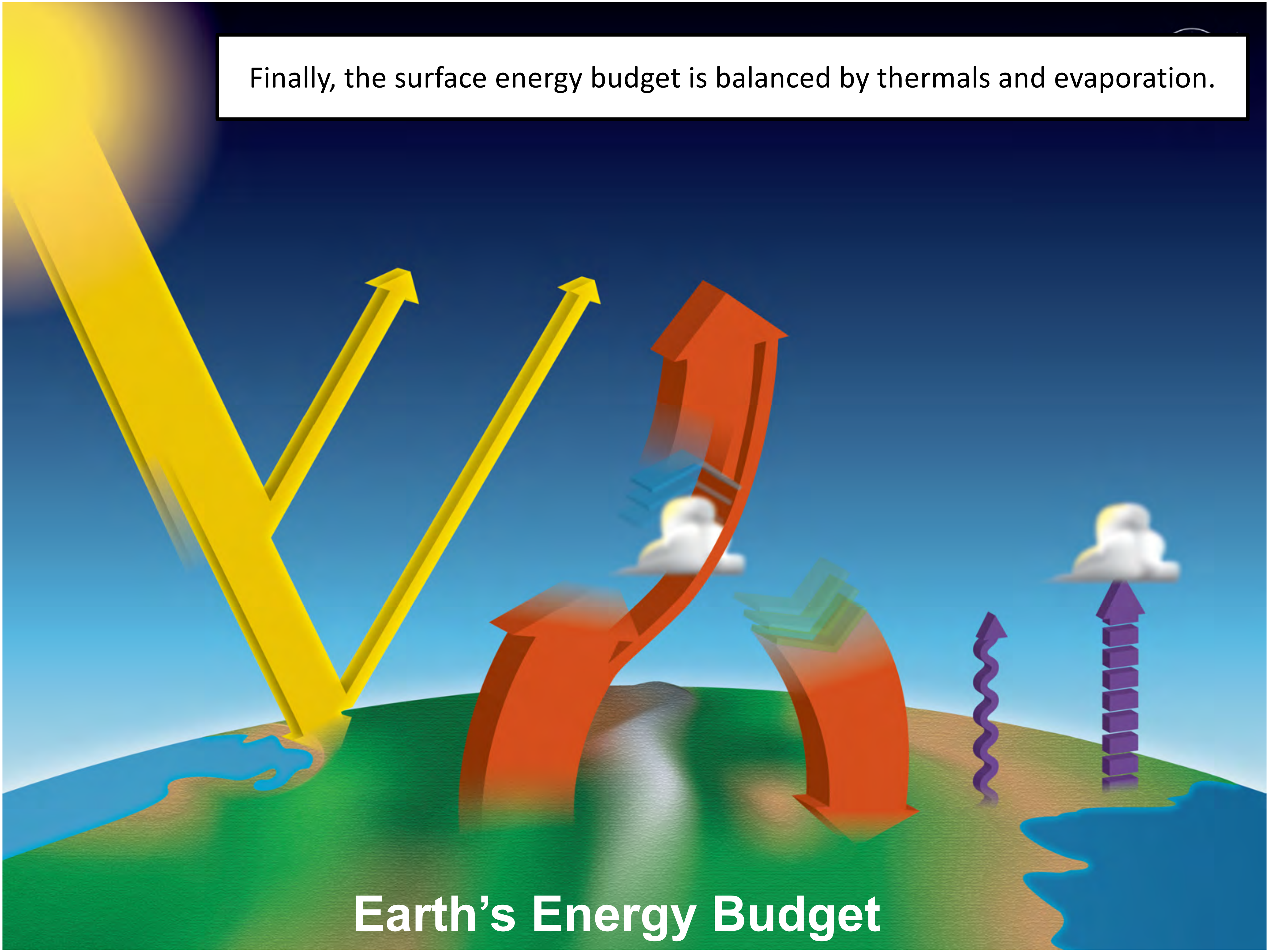
The world in reflected sunlight, May 25, 2001. Clouds, deserts and Arctic ice are bright. The south pole is in winter darkness with no sunlight to reflect.




All of that energy that is absorbed by the Earth doesn't just stay there and build up forever. The Earth system radiates that energy out towards space as heat. Cold objects emit less energy; warm objects emit more.
Earth’s Energy Budget

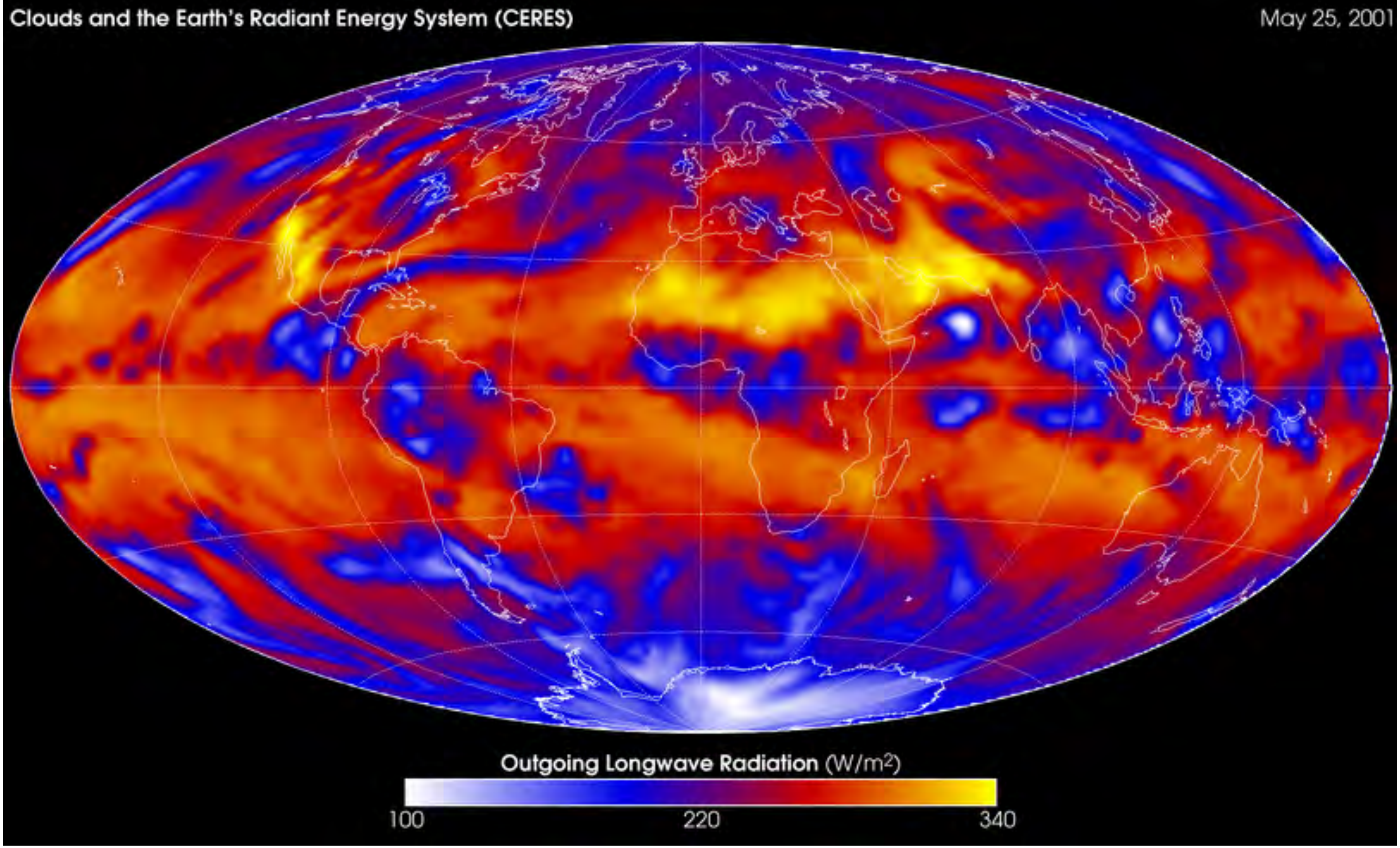

Most of the heat emitted from the surface is stopped on its way back out. Clouds and certain gases in the atmosphere absorb the energy, preventing it from leaving the system. Only a small window allows direct escape.
Earth’s Energy Budget


Energy emitted from those clouds and gases goes in all directions. Some comes back to further warm the Earth. This is the greenhouse effect.
Earth’s Energy Budget

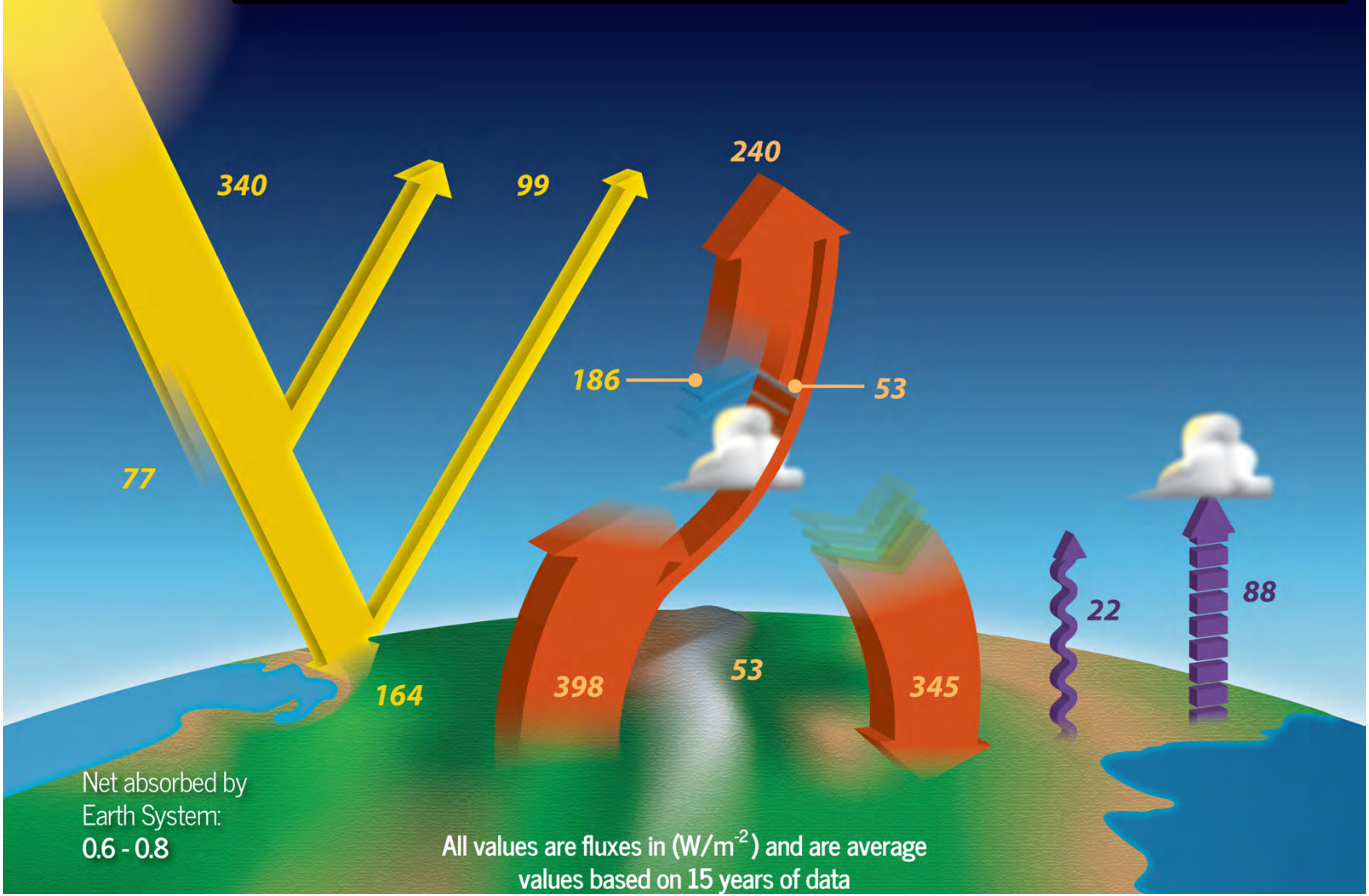

Finally, the surface energy budget is balanced by thermals and evaporation.
Earth's Energy Budget


Together all of these forms of incoming and outgoing energy have resulted in just the right living conditions for us on Earth.
Earth’s Energy Budget

The world in emitted heat, May 25, 2001. Deserts are hot; clouds and polar ice are cold. The south pole is in winter deep freeze.



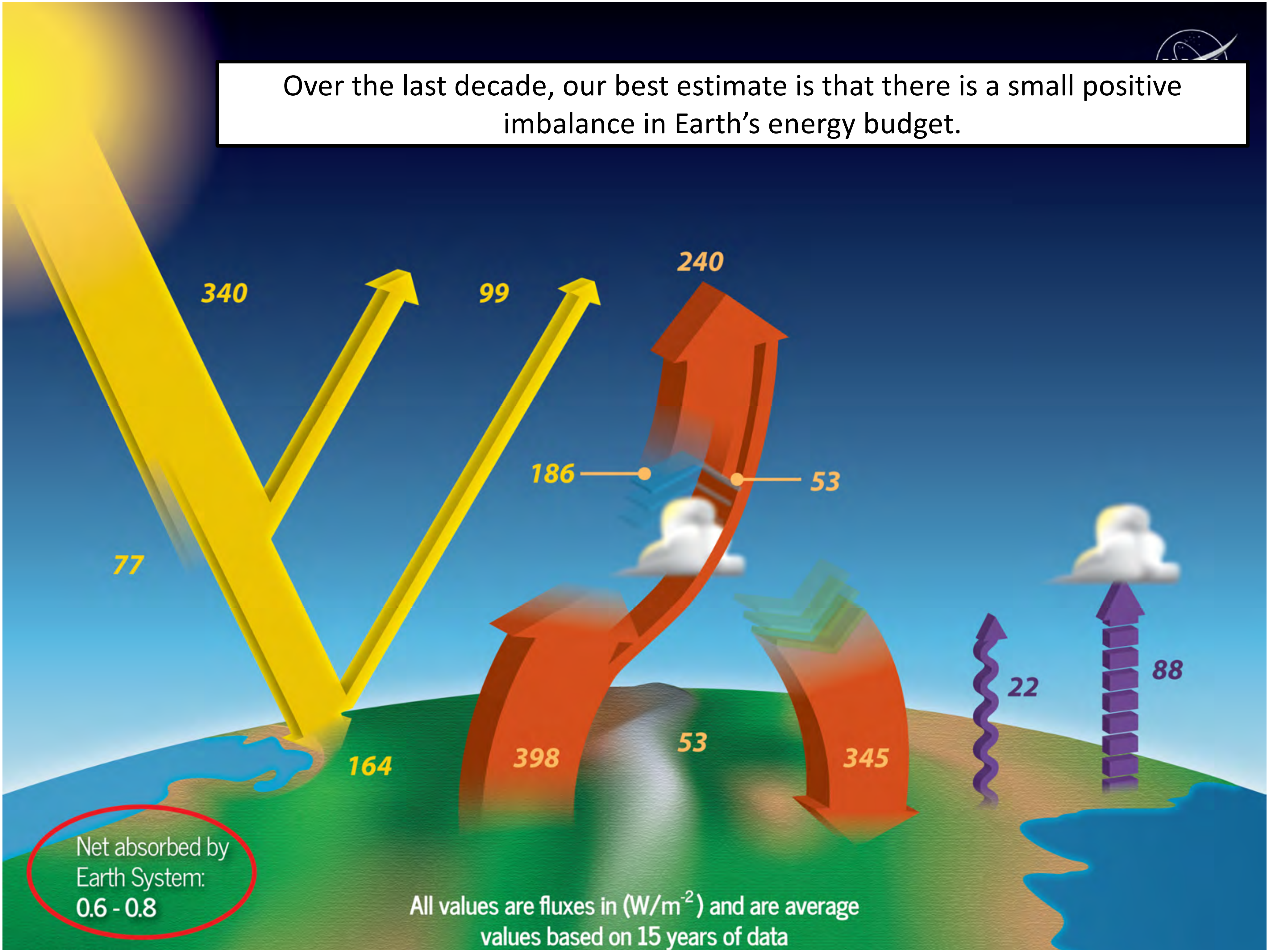
Scientists use satellites, ground-based instruments, aircraft field campaigns, and computer models to determine the magnitude of each flux.



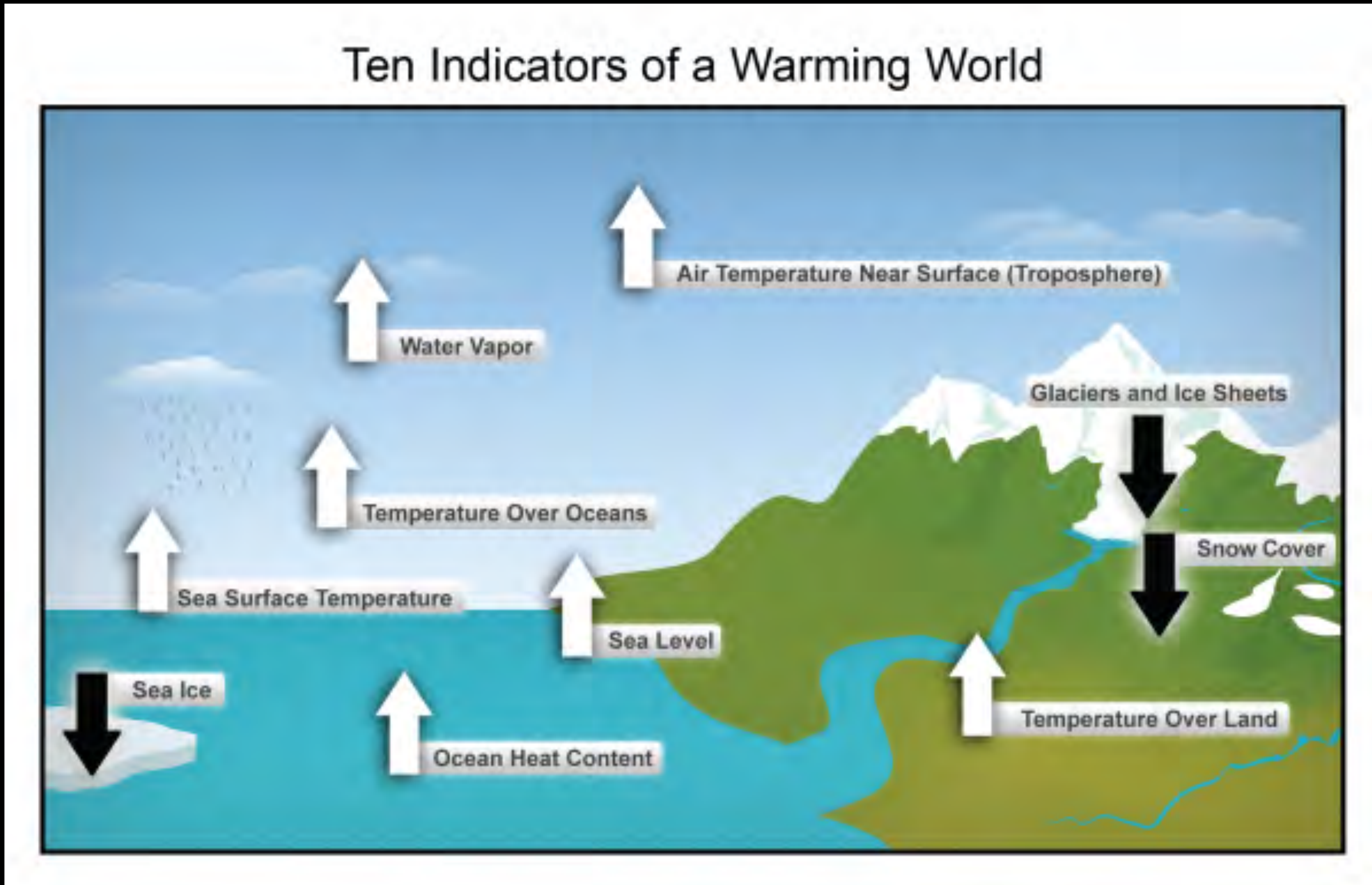


Like your house, anything that increases or decreases the amount of incoming or outgoing energy would disturb Earth's energy balance and would cause global temperatures to rise or fall.

Over the last decade, our best estimate is that there is a small positive imbalance in Earth's energy budget.



This is consistent with several other *lines of evidence* of a warming planet.



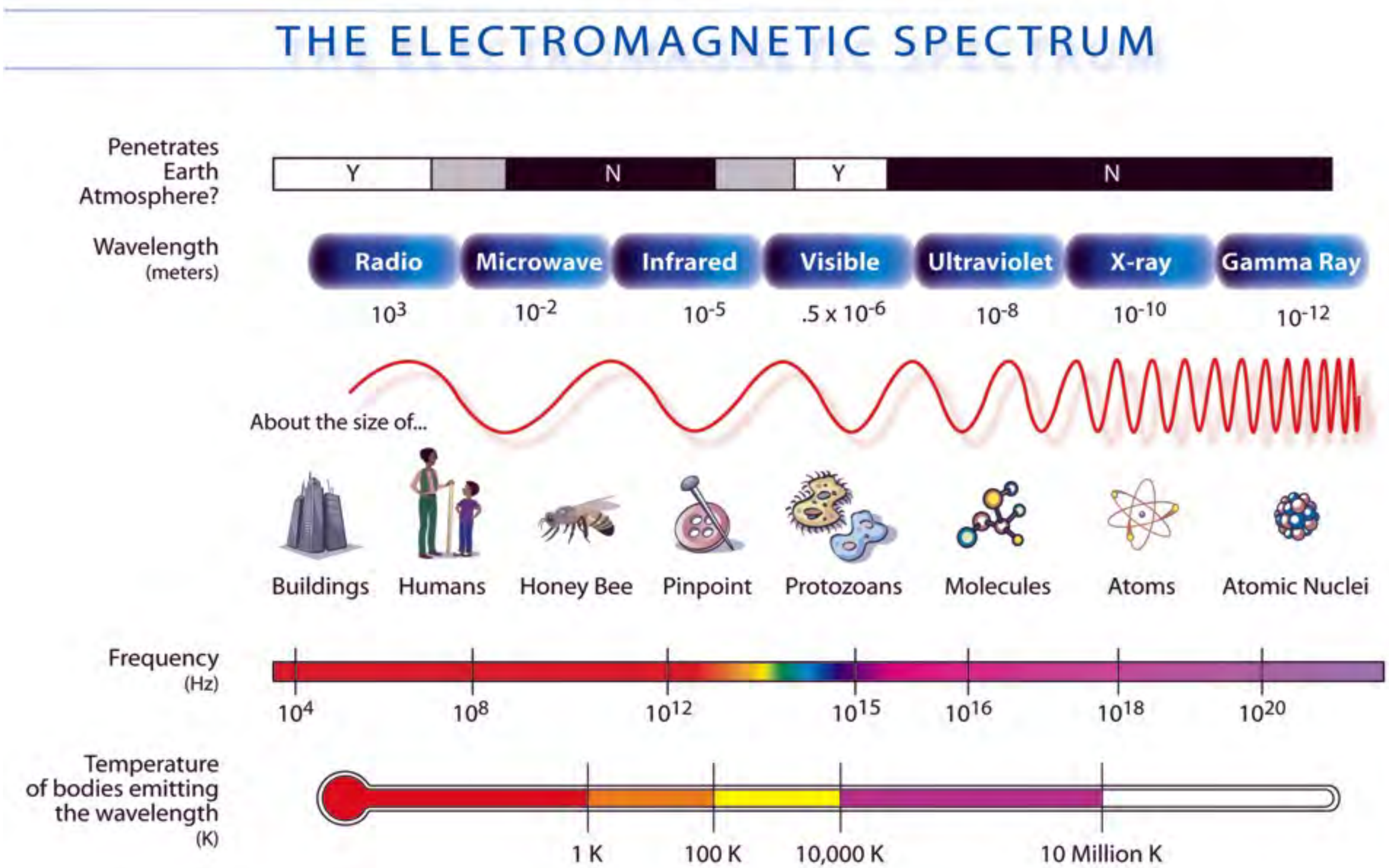
https://www.globalchange.gov/browse/multimedia/ten-indicators-warming-world

The End

… for now

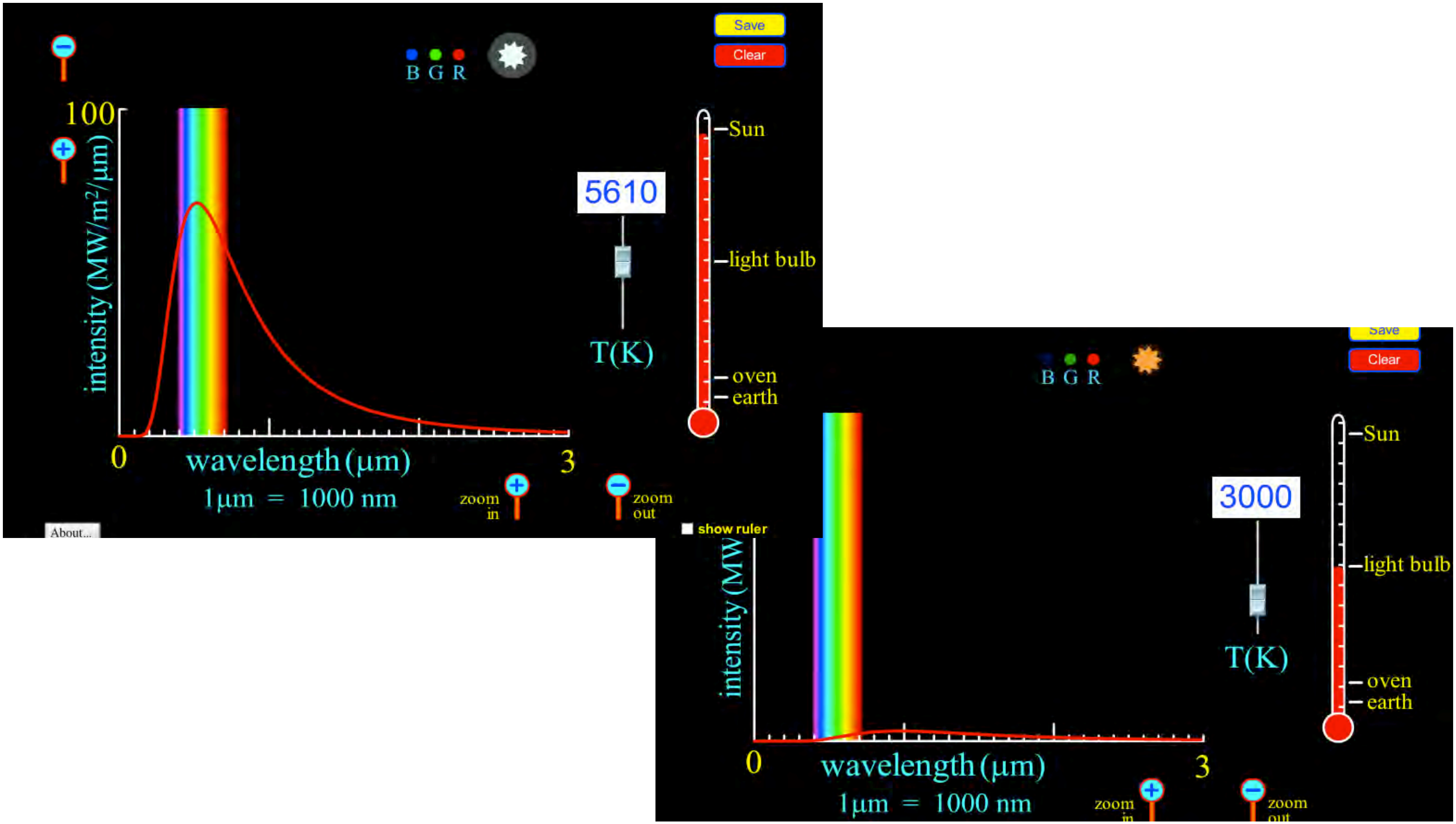
Details behind the story

Teaching Resources: The Electromagnetic Spectrum



https://mynasadata.larc.nasa.gov/basic-page/electromagnetic-spectrum-diagram

The Blackbody Spectrum



https://phet.colorado.edu/en/simulation/blackbody-spectrum

Equil Temp Calculation – An Equation!

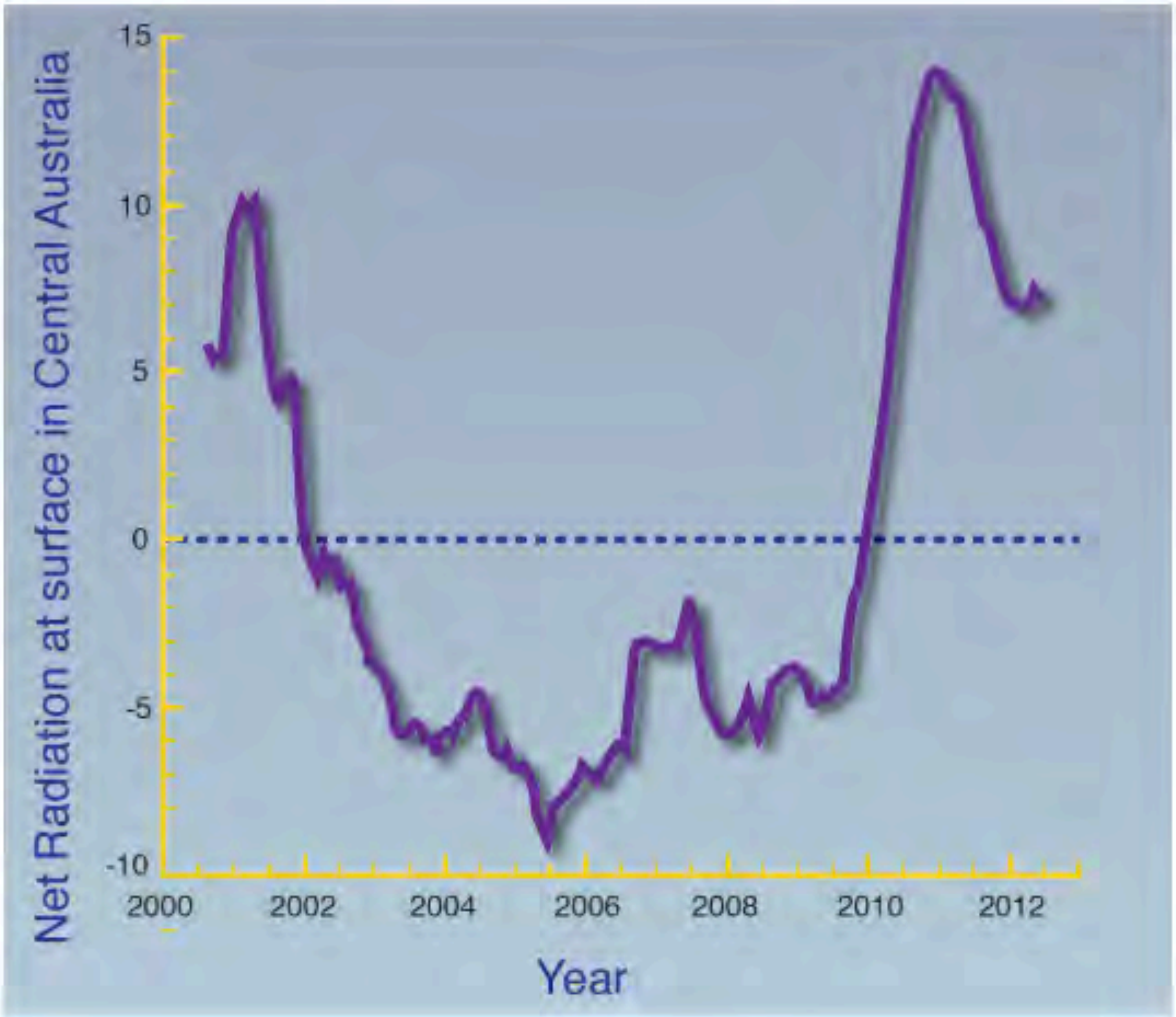
$$\text{Equil Temp} = \text{Temp}_{star} * (1\text{-albedo})^{1/4} * \text{Square root}\left(\frac{\text{Radius}_{star}}{2 * \text{Distance}}\right)$$

Temp_{Sun} ~ 5778K	**Radius_{Sun} ~ 695,500 km**
Albedo ~ 0.3	Distance ~ 149,600,000 km

For Earth: Equil Temp ~254 K = -18 Celsius

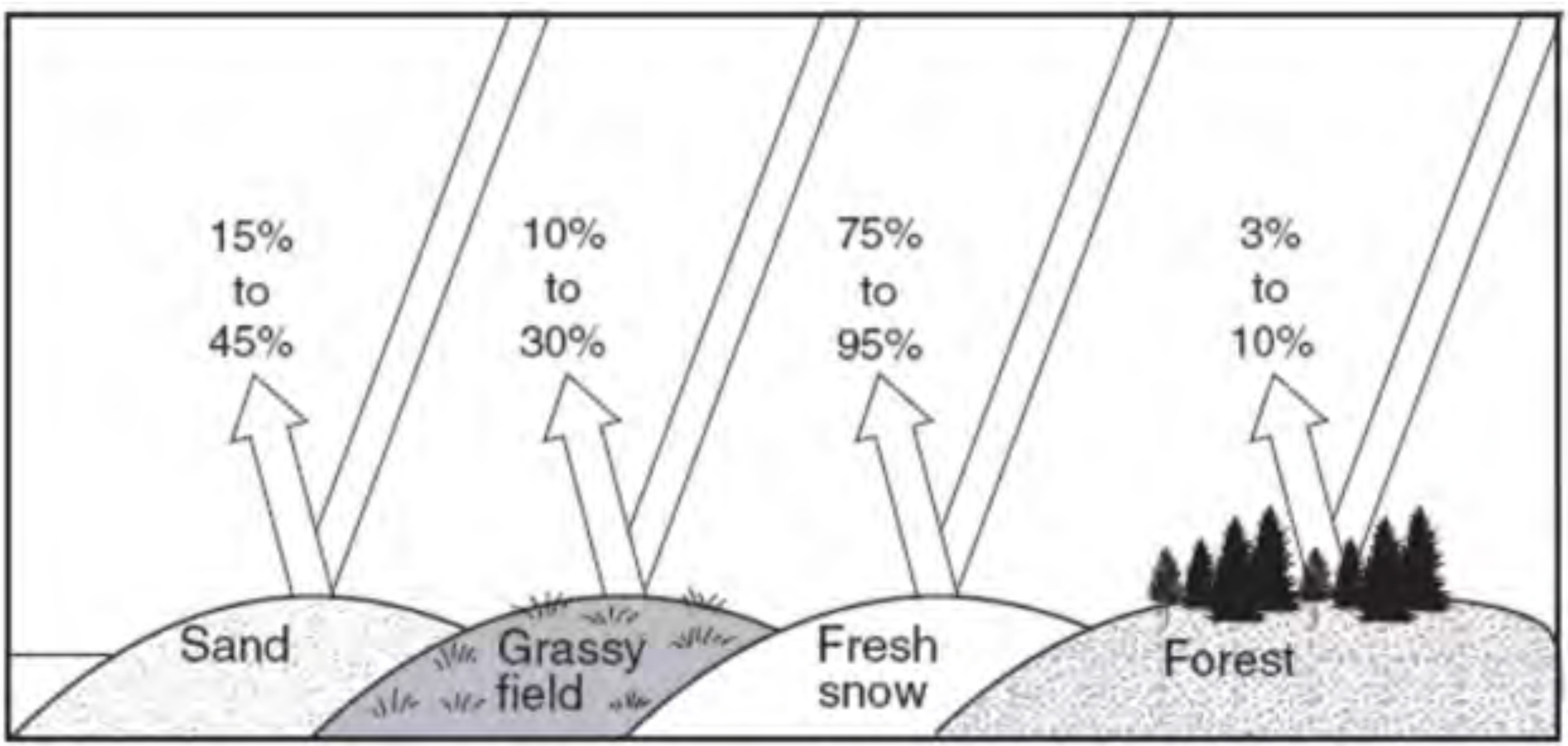
Energy Budget Mini Lesson

CASE STUDY: Surface Effects on Energy Budget - Changes in Central Australia



https://mynasadata.larc.nasa.gov/maps-graphs-and-data/earths-energy-budget

Curriculum Unit Plan



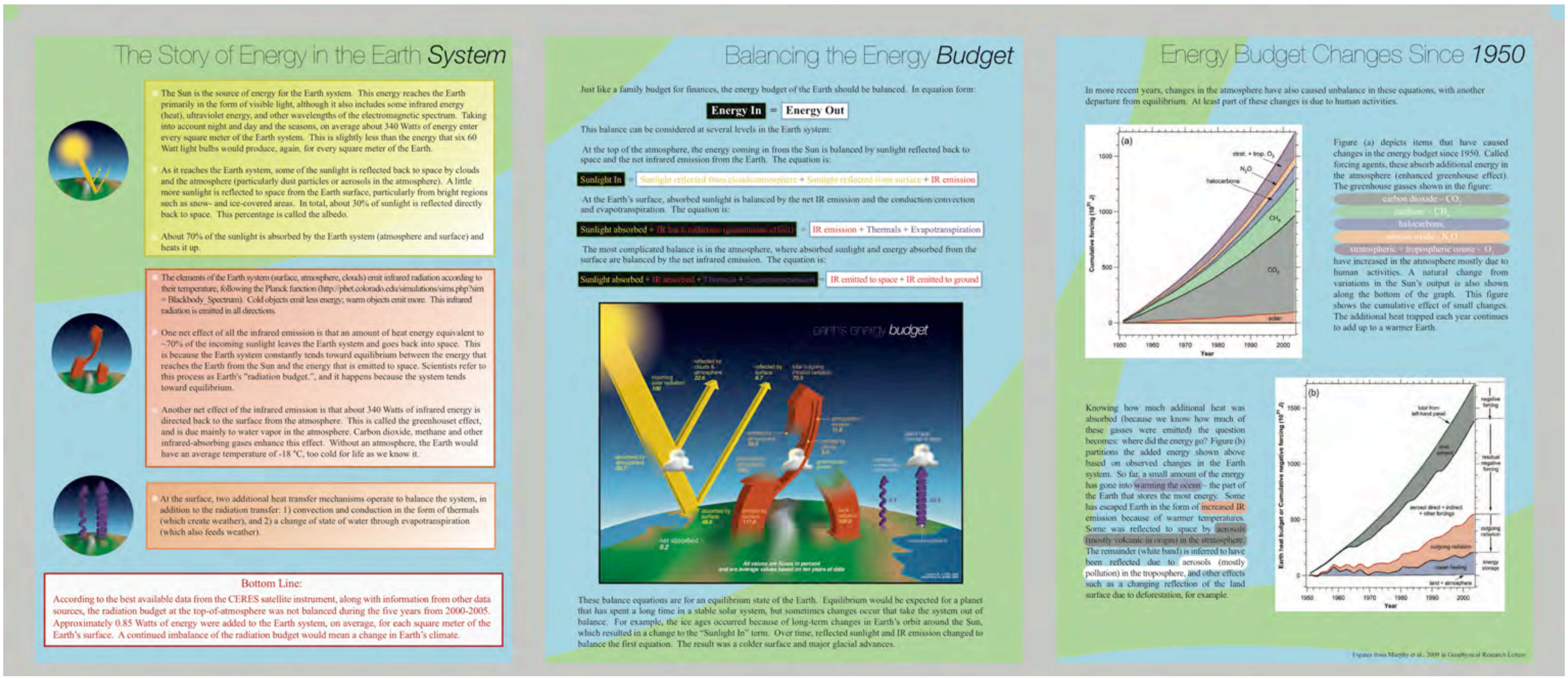
[Unit: Earth's Energy Budget]

Greenhouse Effect

https://www.youtube.com/watch?v=b3NFfWlfj24

Teaching Resources

http://science-edu.larc.nasa.gov/energy_budget/



More Background Resources

https://science-edu.larc.nasa.gov/energy_budget/links.html

Radiative Forcing

Climate Forcings and Global Warming

Radiation Budget

Earth Observatory: Climate and Earth's Energy Budget

MY NASA DATA Mini Lesson

MY NASA DATA Seasonal Cycles

NASA GISS-ICP : Global Equilibrium Energy Balance Interactive Tinker Toy (GEEBIT)

NASA GISS High School Unit Plan [PDF]

PBS Learning Media: Earth's Delicate Energy Balance

PBS Learning Media: Clouds and Earth's Energy Balance Audio Interview (Bruce Wielicki)

UCARConnect : Tracking Earth's Energy Flow

UCAR: Earth's Energy Balance Interactive

Aqua CERES: Tracking Earth's Heat Balance

How CO2 Warms The Climate - Ray Pierrehumbert

eClips Real World Video

Global Energy Balance Animated Diagram

Atmospheric Layers

Layers of the Earth's Atmosphere

Atmosphere layers - Encyclopedia of Earth

General Information

NASA LaRC Science Directorate Home Page

NASA LaRC CERES Home Page

Teaching Resources: Explore Data

[Earth System Data Explorer]